

Effects of Fishmeal or Urea Supplementation on Ruminal Fibre Digestion and Passage Kinetics in Bali Cows

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Abstract. Five non-pregnant Bali cows were used in a 5x5 latin square experimental design with the objective to study the effects of supplementation of graded levels of urea or fishmeal on fibre intake and digestion kinetics in Bali cows consuming low quality tropical grass hay. The animals were given ad libitum access to grass hay or supplemented daily with two levels of urea, i.e. 38 and 74 g, or two levels of fishmeal, i.e. 156 and 312 g. The measured parameters included were intake and apparent digestibility of DM and NDF, in sacco ruminal fibre degradation, and in vivo ruminal NDF digestion and passage kinetics. Intakes of DM and NDF were significantly improved by supplementation of both urea and fishmeal with fishmeal exerted a better effect at low level of supplementation. The increase of intake was mainly associated with the significant increase of rumen in sacco degradation of NDF. However, in vivo rumen digestions of NDF and DNDF were not significantly improved by supplementation due to the increased rumen pool of NDF after protein supplementation. As a result, rumen passage and digestion rates were not affected by supplementation. The effective level of fishmeal and urea supplementation to improve the intake of low quality fibrous tropical grass hay in Bali cows were 152 g/d and 74 g/d, respectively.

Key Words: Bali cows, digestion kinetics, fishmeal, urea

Introduction

Fibre is the main source of energy in Bali cows fed low quality fibrous tropical grass hay (LQH). However, its intake and digestibility are generally very low. Fibre intake could be as low as 8.3 g NDF/kg LW and its digestibility below 40% (Jelantik, 2001). Consequently, when fed alone, LQH provides only about 50-70% of the energy requirement for Bali cows causing the animals to loose weight. The main reason for the low intake and digestibility is due to its very low level of degradable crude protein content (Jelantik, 2001). The rumen ammonia concentration is sub-optimal to support optimal microbial growth and activity, hence unable to undergo efficient fibre degradation. In Bali cattle fed mainly on LQH, the rumen ammonia concentration may fall between 20 and 40 mg/l (Jelantik et al., 2008). In contrast, a ruminal ammonia concentration in the range from 50 to 80 mg/l is required for sufficient microbial growth and activity particularly those microbes responsible for fibre degradation (Mlay et al., 2003).

It advisable that when the diets are composed mostly of mature grass hay, a source of rumen degradable nitrogen should be supplemented. Urea is broadly used as a supplement because it is a concentrated nitrogenous compound and inexpensive. However, improvement of intake and nutrient supply to the animals is often not sufficient to support the desired level of production (Brito et al., 2007). It is common that supplementation of true protein, particularly fishmeal, improves the nutritive value of the roughage to a larger extent compared to supplementation with urea (Dewhurst et al., 2000). Leng (1990) argued that the improvement is due to high undegradable protein content that enhances the total non-ammonia nitrogen flows to the duodenum. However, its effect may also be greater on ruminal fibre digestion kinetics since intake and digestibility are mostly affected by ruminal fermentation (Bandyk et al., 2001; Huhtanen et al., 2007). In addition to nitrogen, the breakdown of true protein also produces branch-chained fatty acids, peptide, pre-form amino acids and minerals which are required

for maximum rumen microbial growth (Broderick and Reinal, 2009). The rate of protein degradation and the release of nitrogen in true protein are also much slower than in urea (Mlay et al., 2003). Hence, the supply of ammonia for rumen microbes is also maintained more evenly and avoids temporary deficiency as in urea supplementation. The different effects of urea and fishmeal supplementations on ruminal fibre digestion kinetics are generally unknown in Bali cattle fed LQH.

This experiment was aimed to provide basic knowledge of fibre kinetics of Bali and how the NDF utilisation of LQH by Bali cows was affected by supplementations of different levels of urea and fishmeal.

Materials and Methods

Animals, Feeds and Treatments

Five dry, non-pregnant Bali cows weighing on average of 189 kg and fitted with permanent rumen cannulae were used in this 5x5 latin square experiment, hence there were 25 experimental units. They were maintained on five tested diets, i.e. low quality native grass hay alone (G) or supplemented with two levels of urea, i.e. 38 and 74 g d⁻¹ (GU₁ and GU₂) and two levels of fishmeal, i.e. 156 and 312 g d⁻¹ (GFM₁ and GFM₂). Fishmeal supplementation was made iso-nitrogenous to the level of urea. For the animals receiving supplemental urea, the diets were supplemented with Na₂SO₄ in amount that gave 1:13 ratio to urea. Grass hay was offered twice a day at 8 AM and 4 PM in amount that gave about 10 to 15 % refusal. The supplemental feeds were fed at the same time. Urea was diluted into 200 to 300 millilitres of water and sprayed onto about one third of the offered grass hay. Additional hay was further offered after the urea-added hay was about to be completely consumed, i.e. about one hour. Water was available on rubber bucket and offered frequently during day and night.

The experiment was arranged in a 5x5 latin square design with 2-week adjustment period followed by a two-week collection period. Of the two-week collection period, one week (third week) was devoted for digestion and in-sacco rumen degradation study. In the fourth

week, rumen evacuation was done during three days (Monday, Wednesday and Friday) at three different times, i.e. 8 AM, 2 and 8 PM.

Parameters, Measurements and Calculations

Crude Fibre and Neutral Detergent Fibre Intake and Total Tract Digestibility

Collection of hay residues from previous feeding was done daily before morning feeding. Daily samplings of offered feeds and residues were done during the third week of each period. The daily collected residues were sampled (about 10%) for DM determination. Feed samples were collected daily and they were composited and stored until the time of DM and NDF determinations. NDF intake (NDFI) was calculated as difference between NDF of offered feeds and residues.

Ruminal in sacco Degradation of Neutral Detergent Fibre (NDF)

In sacco nylon bag technique was used to estimate ruminal degradations of dry matter and NDF of hay. Hay was ground to pass a 1.5 mm screen and about 1 g of the sample was then weighed into a 7.5x10 cm bag made of nylon cloth with a pore size of 37x37 µm². The bags were thereafter incubated in the rumen for 0, 4, 8, 16, 24, 48, and 96 hours. At the time of removal, the bags were then directly frozen. After all bags had been removed from the rumen, they were washed under running tap water for 1 hour. The residues were transferred from the bag into a nitrogen-free filter paper and dried at 105°C for 20 hours. The degradation data were then fitted to the exponential equation using a simultaneous model as described by Mlay et al. (2003):

$$Y(t) = a \quad \text{for } t \leq t_0$$

$$Y(t) = a + b(1 - e^{-c(t-t_0)}) \quad \text{for } t > t_0$$

Where $Y(t)$ is the degraded part at time t ; a is the water soluble fraction; b is the insoluble but potentially degradable fraction; c is the degradation rate constant (in hour⁻¹); t is the incubation time (in hour), and t_0 is the lag time (in hour)

Whereas, the effective degradability (ED) was calculated as $ED = a + ((bc/(c+k)) \cdot e^{-kt_0})$, where a , b and c values are from the previous model and k is the fractional rate of passage.

Table 1. The composition of the experimental diets of Bali cows

Ingredient (kg Dry Matter)	Treatments				
	G	GU ₁	GU ₂	GFM ₁	GFM ₂
Grass hay	<i>Ad libitum</i> *	<i>Ad libitum</i>	<i>Ad libitum</i>	<i>Ad libitum</i>	<i>Ad libitum</i>
Fishmeal	-	-	-	0.156	0.312
Urea	-	0.038	0.074	-	-
Sodium sulfate	-	0.003	0.006	-	-

Grass hay alone (G) or supplemented with 38 gram (GU₁) and 74 gram (GU₂) of urea or 156 gram (GFM₁) and 312 grams (GFM₂) of fishmeal. The hay allowance was about 20% higher than *ad libitum* intake which was obtained during two weeks adjustment period when all animals were given similar diet i.e. hay and 156 gram of fishmeal (GFM₁).

Table 2. Chemical compositions of feedstuffs used in the experiment

Chemical composition (%)	Grass hay	Fishmeal	Urea
Crude Protein (CP)	3.53	63.70	288.00
Ether Extract (EE)	1.39	5.97	-
Crude Fibre (CF)	26.80	0.10	-
Ash	7.80	19.50	-
Nitrogen Free Extract (NFE)	60.50	10.70	-
Organic Matter (OM)	92.20	80.50	100.00
Neutral Detergent Fibre (NDF)	72.60	0	-

Ruminal NDF Digestion Kinetics

A simple method that only requires rumen cannulated cows as proposed by Lund et al. (2006) was conducted to estimate fractional rate of NDF passage from the rumen. Rumen pool size of digestible NDF (DNDF) and indigestible NDF (INDF) was obtained using rumen evacuation technique. Rumen digesta was manually removed from the rumen via cannulae during the 4th week on three different times (8 AM, 2 and 8 PM) in three different days of the week (Monday, Wednesday and Friday) for each period. The rumen content was removed into a perforated rice basket placed into a big plastic basket allowing separation of solid from fluid. The collected rumen fluid was weighed and stirred before sampled for about 0.5 l. The rest of the fluid was immediately returned to the rumen allowing the rumen without fluid for only few minutes. The solid part of the digesta was weighed, mixed and sampled (about 2.5% of total solid digesta). Three 500 g representative rumen samples were obtained by compositing proportionally the solid and fluid samples according to their weight. One sample was dried at low temperature (40°C) in a forced air oven for 48 hours. While the other two were dried in an oven at 105°C for at least 20 hours for DM determination. The DNDF and INDF contents were estimated by the NDF remaining in the

samples of hay, rumen content and faeces after 21 days suspended in the rumen of two cows fed 2/3 hay and 1/3 concentrate at maintenance level for energy.

Digestion and fractional outflow rates of DNDF and INDF were estimated using the following equations calculated as suggested by Huhtanen et al. (2007): K_i (rate of intake, h^{-1}) of DNDF and INDF = (DNDF or INDF intake (kg/d)/rumen pool size of DNDF or INDF (kg))/24 (h/d); K_p (rate of passage, h^{-1}) = (Faecal outflow of INDF intake (kg/d)/rumen pool size of INDF (kg))/24 (h/d); K_d (rate of digestion, h^{-1}) = K_i of DNDF - K_p of DNDF. Rumen digestibility of NDF (RDDNDF) = $fd \times (K_d / (K_d + K_p))$, where fd was the fraction of DNDF relative to NDF.

These calculations were done assuming that rumen NDF pool sizes and fluxes were at steady state and that 21 days incubation time in the rumen was an accurate measure of indigestible fibre by *in vivo*.

Chemical Analyses

Diets, ingredients, residues, faeces and rumen digesta were analysed for DM, CF and NDF contents. The samples were dried in a forced-air oven at 40°C for 48 hours, ground using a willey mill (1 mm screen) and analysed for CF, NDF and ADF. Crude fibre was analyzed using acid and followed by base solution according to AOAC (1990). Whereas, NDF and ADF contents were determined using detergent

analysis as Van Soest et al. (1991) excluding the use of alpha-amylase enzyme.

Statistical Analyses

All data were statistically analysed using Proc. GLM (SAS Institute, 2000). The model used was consistent with Latin square design: $Y = \mu + C + P + T + E$ or $Y = \mu + C + P + E$, where μ : overall mean, P: systematic effect of period, C: systematic effect of cow, T: fixed effect of treatment, and E: residual error.

Results and Discussion

Dry Matter and NDF Intake

Dry matter and NDF intakes of Bali cows maintained on LQH alone or supplemented with two levels of urea or fishmeal are presented in Table 3. Grass hay and particularly total dry matter intakes were significantly increased ($P < 0.01$) by supplementation of graded amount of protein sources. Similarly, the intake of CF, NDF and ADF were significantly improved by protein supplementation. This marked incremental effect of protein supplementation on the intake of LQH was in accordance with other results (Jelantik, 2001; Dixon et al., 2003; Jelantik et al., 2008) where low quality forages or cereal straws containing less than 7% CP were supplemented with protein rich feeds. Our result demonstrates how LQH can be appreciably increased simply by spraying urea into the hay. With urea supplementation, the highest intake was obtained when the animals were supplemented with 74 g/d urea (GU_2). Meanwhile, to obtain a similar effect as urea, less supplemental CP was required with FM. This indicated that FM was more efficient in improving fibre intake in Bali cows consuming LQH. Dixon et al. (2003) also reported that true protein exerted a better effect in improving the nutrient intakes in cattle maintained on LQH.

Rumen Pool Size (RPS)

Rumen pool size in Bali cows consuming low-quality grass hay and the effect of graded level of nitrogen supplementation is presented in Table 4. It was shown that Bali cattle has rumen capacity varied between 30-38 kg at wet basis (15-20% live weight, LW), 4.15-5.63 kg DM (2-3% LW) or 3.11-3.94 kg NDF (1.6-2.0

% LW). It appeared that rumen capacity of Bali cows is comparable to other tropical breeds but markedly higher than European breeds. Mlay et al. (2003) reported that RPS of wet digesta, DM and NDF of Boran cows were 18-19% LW, 2.6-2.9% LW and 1.9-2.2% LW respectively. Whereas, Huhtanen et al. (2007) reported that Frisian bulls and Ayrshire heifers had RPS of wet 10% LW, DM=1% LW and NDF=0.6% LW. This indicates that Bali cattle could have high capacity to digest low-quality, high-fibre feeds. Intake and digestibility is expected to be higher in animals with higher RPS than those with lower RPS (Poppi et al., 2000).

RPS of Bali cattle maintained on LQH was improved significantly ($P < 0.05$) with supplementation. RPS of supplemented animals (GFM_2) were 25% higher than unsupplemented animals (G). The increase in RPS was related closely to the increasing trend of intake. Indeed, the increase of RPS was best related to the increased intake. This is rarely reported in the literature and it seems to deviate from the 'fill' theory which assumes a steady state condition. It is commonly agreed that intake in ruminant animals are limited by rumen physical fill, i.e. physical regulation of intake which is most likely to occur in ruminants fed roughage (Forbes, 1995). In this theory, the animals will stop eating when their rumen has been fully loaded, hence it implies that RPS is kept constant, i.e. a steady state condition. Our result demonstrates that RPS may not be constant. Rather, it varies 'to a certain extent' according to different factors. RPS was found in this experiment to be widely varied with time of the day, i.e. being the lowest in the morning before feeding. Previously Cannas et al. (2003) reported that RPS was increased with increasing forage NDF intake. Similarly, RPS increased as dry matter intake of LQH increased (Dixon et al., 2003).

Mechanism behind the increase of RPS with protein supplementation was not clearly discussed especially to explain the higher intake of FM compared to urea supplementation. Bandyk et al. (2001) hypothesized that cattle were able to accommodate higher gut "fill" when their nitrogen status is improved. In this case, the higher increase of RPS in FM supplemented animals might be due to higher

Table 3. Dry matter and fibre intakes of Bali cows

Variables	Treatments					SEM	Probability
	G	GU ₁	GU ₂	GFM ₁	GFM ₂		
Hay (kgDM/d)	2.16 ^a	2.71 ^b	3.05 ^c	3.04 ^c	3.01 ^c	0.12	<0.01
Total (kgDM/d)	2.16 ^a	2.75 ^b	3.07 ^c	3.19 ^c	3.32 ^c	0.12	<0.01
Crude Fibre (g/d)	341 ^a	382 ^b	481 ^d	442 ^c	460 ^d	27.0	0.01
NDF (kg/d)	1.57 ^a	1.97 ^b	2.21 ^c	2.21 ^c	2.18 ^c	0.87	<0.01
ADF (kg/d)	0.90 ^a	1.13 ^b	1.27 ^c	1.27 ^c	1.25 ^c	0.05	<0.01

Grass hay alone (G) or supplemented with 38 gram (GU₁) and 74 gram (GU₂) of urea or 156 gram (GFM₁) and 312 grams (GFM₂) of fishmeal. The hay allowance was about 20% higher than ad libitum intake which was obtained during two weeks adjustment period when all animals were given similar diet i.e. hay and 156 gram of fishmeal (GFM₁).

Values bearing different superscript at the same row differ significantly (P<0.05).

NDF : Neutral Detergent Fibre; ADF : Acid detergent fibre; SEM : Standard error of means; *linear effect.

Table 4. Rumen pool size in Bali cows

Variables	Treatments					SEM	P
	G	GU ₁	GU ₂	GFM ₁	GFM ₂		
Solid (kg)	27.90 ^a	33.30 ^b	34.10 ^c	34.00 ^c	34.70 ^c	0.90	<0.01
Liquid (kg)	2.36 ^a	2.74 ^b	3.59 ^b	3.29 ^a	3.30 ^a	0.25	<0.01
Total (kg)	30.30 ^a	36.00 ^b	37.70 ^b	37.30 ^b	38.00 ^b	0.93	<0.01
DM (%)	13.70	14.10	13.00	13.30	13.90	0.01	0.3
DM (kg)	4.15 ^a	5.07 ^b	4.91 ^b	4.96 ^b	5.63 ^c	0.21	0.02
NDF (kg)	3.11 ^a	3.74 ^b	3.65 ^b	3.61 ^b	3.94 ^c	0.15	0.02
DNDF (kg)	1.36	1.47	1.62	1.63	1.69	0.10	0.2
INDF (kg)	1.74 ^a	2.27 ^c	2.02 ^b	1.98 ^b	2.25 ^c	0.11	0.03

Grass hay alone (G) or supplemented with 38 gram (GU₁) and 74 gram (GU₂) of urea or 156 gram (GFM₁) and 312 grams (GFM₂) of fishmeal. The hay allowance was about 20% higher than ad libitum intake which was obtained during two weeks adjustment period when all animals were given similar diet i.e. hay and 156 gram of fishmeal (GFM₁).

Values bearing different superscript at the same row differ significantly (P<0.05).

SEM : standard error of means; P : probability.

amino acids supply than urea supplemented animals. Generally, supplementation of rumen degradable protein especially fishmeal has a better effect in increasing NAN flow from the rumen than urea (Dixon et al., 2003; Brito et al., 2007). In addition, with the better provision of gluconeogenic compounds (i.e. amino acids) the removal of VFA from the blood would be increased. This in turn stimulates intake (Wickersham et al., 2004) and increases RPS (Cannas et al., 2003).

Rates of Rumen Digestions (kd) and Passages (kp)

Rate of digestion of NDF fractions of tropical grass hay was estimated in this experiment by two techniques i.e. through in sacco study with nylon bag technique and in vivo study utilising rumen evacuation technique (RET). Results were expected to provide sufficient explanation for the improvement of intake found in this experiment since increased intake could be attributable to either through increased rumen digestion or enhanced passage rate or both

(Poppi et al., 2000; Lund et al., 2006). Rumen in sacco degradation is believed to provide indication on rumen microbes activity. Whereas, in vivo study measures the digestion kinetics that actually occur in the rumen.

Results of this experiment showed that there was a significant increase (P<0.05) in rumen in sacco NDF degradation after supplementation of both urea and fishmeal (Table 5). The effective rumen NDF degradability at 1% per hour passage rate (ED1) of grass hay was significantly improved by increasing level of protein supplementation in both supplements. The improvement was more profound in FM compared to urea supplemented cows. The increase of degradability in urea-supplemented animals reached a *plateau* after the first level of supplementation. This finding therefore clearly indicates that the increased NDF intake found in this experiment is associated to the improved NDF rumen degradation after supplementation.

When the effect of the two supplements were compared, it was clear that fishmeal was

Table 5. In sacco degradation and in vivo rate of digestion (kd) and passages (kp) in Bali cows

Variables	Treatments					SEM	P
	G	GU ₁	GU ₂	GFM ₁	GFM ₂		
In sacco study :							
c	0.02 ^a	0.02 ^b	0.02 ^a	0.03 ^b	0.03 ^b	0.004	0.01
Kp*	0.01	0.01	0.01	0.01	0.01	-	-
ED ₁	38.3 ^a	40.8 ^b	39.8 ^{ab}	42.2 ^c	44.1 ^d	1.1	0.03
In vivo study :							
Kd NDF	0.011	0.013	0.013	0.011	0.011	0.001	0.3
Kd DNDF ¹	0.021	0.024	0.026	0.025	0.023	0.002	0.5
Kp NDF	0.010	0.010	0.014	0.013	0.013	0.001	0.4
Kp DNDF	0.009	0.011	0.009	0.011	0.011	0.001	0.2
Kp INDF	0.014	0.012	0.016	0.016	0.014	0.002	0.3
RDNDF ¹	35.70	38.10	35.60	34.90	35.30	1.520	0.5
RDDNDF ²	61.9	66.1	61.7	60.5	61.2	2.64	0.6

Grass hay alone (G) or supplemented with 38 gram (GU₁) and 74 gram (GU₂) of urea or 156 gram (GFM₁) and 312 grams (GFM₂) of fishmeal. The hay allowance was about 20% higher than ad libitum intake which was obtained during two weeks adjustment period when all animals were given similar diet i.e. hay and 156 gram of fishmeal (GFM₁).

Values bearing different superscript at the same row differ significantly (P<0.05).

c : degradation rate estimated in sacco; SEM : standard error of means; P : probability; Ed₁ : effective degradability at passage rate 1% per hour; * estimated; ¹Rumen Digestibility of NDF (RDND) = (DNDF disappeared in the rumen/rumen pool of DNDF)/24 h; ²Rumen digestibility of DNDF (RDDND) = ((DNDF intake/NDF intake) x kd DNDF)/(kd DNDF + kp INDF).

the better supplement in improving the extent of ruminal NDF degradation compared to urea. The degradation rate was also faster with FM than with urea supplementation, which is in agreement to the result reported by Mlay et al. (2003).

The positive effect of supplementation on degradation rate is apparently exerted through the fact that nitrogen supplementation increases rumen ammonia concentration to a level that suffices the microbial requirement. Rumen ammonia concentration is commonly improved from suboptimal level, i.e. 26.7 mg/l to 34 mg/l (Jelantik et al., 2008) to a level above 80 mg/l which is the minimum level required for efficient ruminal NDF degradation (Jelantik, 2001; Detmann et al., 2009). However, rumen ammonia concentration is certainly not sufficient to explain the difference in degradation rate between different nitrogen sources. Rumen degradation was higher in FM supplemented cows compared to that in urea supplemented cows despite their lower ammonia content (Jelantik, 2001). In many circumstances, the better effect of FM over urea on degradation was resulted by more even ammonia released or less diurnal variation by the former. Due to the very rapid conversion of urea, ammonia concentration quickly peaks far above the required level but then decreases rapidly to the basal of insufficient level,

resulting most of the time ammonia falls below the level which reduces the efficiency of microbial synthesis (Jelantik et al., 2008). The superiority of FM over urea in improving the ruminal degradation of LQH and increasing intake was also exerted through the ability of fishmeal to provide pre-formed amino acids, peptides, and branch-chained fatty acids when it was degraded in the rumen (Broderick and Reynal, 2009). These intermediary fermentation products were specifically required by fibre degrading microbes for maximum growth and rumen fibre fermentation.

Despite the clear evidence that improved intake might be due to improved rumen degradation of NDF, results of the in vivo rumen digestion rate estimated using rumen evacuation technique (RET) indicated that the increase was less and statistically insignificant. In addition, the difference between the protein sources and the level of supplementation were not apparent. The main reason for this was that rumen pool size (RPS) increased significantly following closely the increasing trend of intake. The size of faecal outflows of NDF, DNDF and INDF were in fact, significantly increased (P<0.05) by supplementation. However, since RPS was increased to a larger extent compared to the increase of faecal outflow, the rate of digestion (kd of DNDF) became less affected (P>0.05) by supplementation.

Rate of passage of NDF and INDF of Bali cattle in this experiment was in average 0.012 h⁻¹ and 0.0144 h⁻¹ respectively. It appears that rate of passage of NDF fractions in Bali cows consuming low quality forages is slightly slower than in other breeds. Mlay et al. (2003) passage rates of INDF varied from 0.02 to 0.026 h⁻¹ in Boran cattle. Similarly, NDF passage rates of 0.032-0.043 h⁻¹ were recorded in Sahelian cattle (Schelct et al., 2007). With slower NDF passage rate, Bali cattle is expected to have higher capacity to digest low quality fibrous feeds in the rumen. A slower passage rate means a longer retention time of feeds in the rumen which results in increasing rumen degradation.

Since passage rate was also calculated from RPS, the increased RPS also means that the passage rate is kept unaffected despite the significant increase in faecal NDF outflow after supplementation. If the RPS of INDF is constant at for example 1.74 kg (i.e. in control animals), the passage rate will be increased from 1.4% to 1.8% per hour when faecal INDF outflow increases from 0.56 to 0.77 kg/d.

Conclusions

Supplementations of both urea and fishmeal significantly improve the intake of DM and fibre fractions with fishmeal exerted a better effect at low level of supplementation. The increase of intake is mainly associated with the increase of rumen pool size and improvement in rumen microbial activities measured as a significant increase of rumen *in-sacco* NDF degradation after supplementation. This marked increase of RPS results in the rumen passage and digestion rates and hence in vivo rumen digestion of NDF and DNDF are kept unaffected by supplementation. Bali cows have capacity to digest LQF as equipped by high RPS, slow passage rate and high digestive efficiency compared to other breeds especially to European breeds.

References

- AOAC. 1990. Association of Official Agricultural Chemists. Official Methods of Analyses. 15th Edition AOAC, Washington D.C. Vol. 1:62 pp.
- Bandyk CA, RC Cochran, TA Wickersham, EC Titgemeyer, CG Farmer and JJ Higgins. 2001. Effect of ruminal vs post-ruminal administration of degradable protein on utilization of low-quality forage by beef steers. J. Anim. Sci. 79:225-231.
- Brito AF, GA Broderick and SM Reynal. 2007. Effects of different protein supplements on omasal nutrient flow and microbial protein synthesis in lactating dairy cows. J. Dairy Sci. 90:1828-1841.
- Broderick GA and SM Reynal. 2009. Effect of source of rumen-degradable protein on production and ruminal metabolism in lactating dairy cows. J. Dairy Sci. 92:2822-2834.
- Cannas A, PJ Van Soest and AN Pell. 2003. Use of animal and dietary information to predict rumen turnover. Anim. Feed Sci. Technol. 106:95-117.
- Detmann E, MF Paulino, HC Mantovani, SCV Filho, CB sampaio, MA de Souza, I Lazzarini and KSC Detmann. 2009. Parameterization of ruminal fibre degradation in low quality tropical forage using Michaelis-Menten kinetics. Livest. Sci. 126:136-146.
- Dewhurst RJ, DR Davis and RJ Merry. 2000. Microbial protein supply from the rumen. Anim. Feed Sci. Technol. 85:1-21.
- Dixon RM, BJ Hosking and AR Egan. 2003. Effects of oilseed meal and grain-urea supplements fed infrequently on digestion in sheep. 1. Low quality grass hay diets. Anim. Feed Sci. Technol. 75-94.
- Huhtanen P, U Asikainen, M Arkilla and S. Jaakkola. 2007. Cell wall digestion and passage kinetics estimated by marker and in situ methods or by rumen evacuations in cattle fed hay 2 or 18 times daily. Anim. Feed Sci. 133:206-207.
- Jelantik IGN. 2001. Improving Bali Cattle (*Bibos banteng* Wagner) Production Through Protein Supplementation. RVAU, Copenhagen, Denmark.
- Jelantik IGN, HLL Belli and WMM Nalley. 2008. Effect of different levels and sources of rumen degradable protein on nitrogen metabolism in Bali cows fed low quality tropical grass hay. In : Proc. International Seminar on Manag. Strategy of Anim. Health and Prod. Control on Anticipation Global Warming for Achievement of Millennium Development Goals. UNAIR, Surabaya, 3-4 June 2008. Pp. 137-141.
- Leng RA. 1990. Factors affecting the utilization of poor quality forages by ruminants particularly under tropical conditions. Nut. Res. Rev. 3:277-303.
- Lund P, MR Weisbjerg and T Hvelplund. 2006. Passage kinetics of fibre in dairy cows obtained from duodenal and faecal ytterbium excretion: effect of forage type. Anim. Feed Sci. Technol. 128:229-252.
- Mlay PS, AE Pereka, MR Weisbjerg, T Hvelplund and J Madsen. 2003. Digestion and passage kinetics of fibre in mature dairy heifers maintained on poor quality hay as affected by the source and

- level of nitrogen supplementation. Anim. Feed Sci. Technol. 109:19-33.
- Ortiz-Rubio MA, ER Ørskov, J Milne, and HMA Galina. 2007. Effect of different sources of nitrogen on in situ degradability and feed intake of Zebu cattle fed sugarcane tops (*Saccharum officinarum*). Anim. Feed Sci. 139:143-158.
- Poppi DP, J France and SR McLennan. 2000. Intake, Passage and Digestibility. In: Feeding System and Feed Evaluation Models. MK Theodorou and J France (eds) CABI Publishing, UK.
- SAS., 2000. SAS/STAT User Guide. SAS Institute Inc. Cary, NC.
- Schlecht E, H Richter, S Fernandez-Rivera and K Becker. 2007. Gastrointestinal passage of Sahelian roughages in cattle, sheep and goats, and implications for livestock-mediated nutrient transfers. Anim. Feed Sci. Technol. 137:93-114.
- Van Soest PJ, J B Robertson and B A Lewis. 1991. Methods for dietary fibre, neutral detergent fibre and non-starch polysaccharides in relation to animal nutrition. J. Dairy Sci. 74:3583-3597.
- Wickersham TA, RC Cochran, EC Titgemeyer, CG Farmer, EA Klevesahl, JI Arroquy, DE Johnson, and DP Gnad. 2004. Effect of postruminal protein supply on the response to ruminal protein supplementation in beef steers fed a low quality grass hay. Anim. Feed Sci. Technol. 115:19-36.